Microphysics of Air-Sea Exchanges

O. B. Brown
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149-1098
phone: (305) 361-4000 fax: (305) 361-4711 email: obrown@rsmas.miami.edu

R. H. Evans
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149-1098
phone: (305) 361-4799 fax: (305) 361-4622 email: revans@rsmas.miami.edu

M. A. Donelan
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149-1098
phone: (305) 361-4717 fax: (305) 361-4701 email: mdonelan@rsmas.miami.edu

P. J. Minnett
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149-1098
phone: (305) 361-4104 fax: (305) 361-4622 email: pminnett@rsmas.miami.edu

Award Number: N00014-01-1-0203
http://www.rsmas.miami.edu/groups/rsg.html

LONG-TERM GOALS

The research efforts are targeted at improving our understanding of the microphysics of air-sea exchanges, especially the physics of the oceanic thermal skin and diurnally-influenced layers. This will lead to better assimilation of satellite-derived sea-surface temperature (SST) fields into meaningful climatologies and to more physically-based applications of satellite data to studies of air-sea interactions and to other naval applications. The constellation of the new generation of satellites with infrared radiometers for SST measurements has a range of local over-pass times and, because of the diurnally forced fluctuation in SST and of the fluctuations of the skin effect in response to differing air-sea fluxes, this creates a problem in combining these fields into a reliable, consistent composite analysis. The results of this new research will improve the reliability of such composite analyses for naval applications.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Microphysics of Air-Sea Exchanges**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Rosenstiel School of Marine and Atmospheric Science,,University of Miami,4600 Rickenbacker Causeway,,Miami,,FL, 33149**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The research efforts are targeted at improving our understanding of the microphysics of air-sea exchanges, especially the physics of the oceanic thermal skin and diurnally-influenced layers. This will lead to better assimilation of satellite-derived sea-surface temperature (SST) fields into meaningful climatologies and to more physically-based applications of satellite data to studies of air-sea interactions and to other naval applications. The constellation of the new generation of satellites with infrared radiometers for SST measurements has a range of local over-pass times and, because of the diurnally forced fluctuation in SST and of the fluctuations of the skin effect in response to differing air-sea fluxes, this creates a problem in combining these fields into a reliable, consistent composite analysis. The results of this new research will improve the reliability of such composite analyses for naval applications.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

OBJECTIVES

The objectives are to achieve a better understanding of the physics of the near-surface temperature gradients; specifically how they respond to different flux and wind regimes. This improved knowledge will be applied to providing a better description to the diurnal temperature variability in the coastal waters around the US, and to a physically-based approach to time-compositing SST fields derived from infrared imaging radiometers on earth observation satellites.

APPROACH

The experimental approach consists for two sets of measurements – one in a new laboratory facility and the other in the field.

The new Air-Sea Interaction Saltwater Tank (ASIST) at RSMAS will be used to provide a range of wind speed and air-sea flux regimes in which the thermal skin effect can be studied. The skin temperature will be measured by mounting a very accurate Fourier Transform Infrared spectroradiometer, M-AERI (Marine-Atmosphere Emitted Radiance Interferometer – Minnett et al, 2001) mounted above the flume. M-AERI which measures infrared radiance in the wavelength range of 3-18 μm at a spectral resolution of approximately 0.5 cm^{-1}.. The *in situ* gradients will be measured by new microthermometers mounted on a rig so they can profile through the uppermost tens of centimeters and through the surface. The motion of the rig will be coupled to the wave-follower in the tank so that the profile is measured at a constant phase relationship to the surface waves. Video, laser systems and hot-film velocimetry will be used to determine the flow fields below the interface.

The experimental technique will be extended to a field campaign on a research ship (leveraging a cruise opportunity provided through separately funded programs). The microthermometers will be mounted on SkinDeEP (Skin Depth Experimental Profiler; Ward and Minnett, 2001; Ward et al, 2002).

The third component of the project is the analysis of SST fields retrieved from measurements of the GOES infrared imager to determine the properties of the diurnal modulation of the SST in US coastal waters. .

WORK COMPLETED

The foci of the activities of the first year of this project have been on the development of instruments, electronic interfaces, experimental rigs and experimental procedures for the ASIST experiments; and on the generation of optimized atmospheric correction algorithms for GOES SST measurements.

A rig has been built to support an M-AERI above the ASIST to measure the water surface skin temperature. An aluminum structural base approximately 2.5 m in height was constructed to allow the M-AERI to sit as close as possible to the edge of the tank. The M-AERI viewed the water surface of the tank at a 34° angle so as to look at a spot approximately midway between the tank walls. A cover was constructed for the tank with an elliptical opening through which the M-AERI viewed the water surface. A tube was attached between the opening and the M-AERI mirror in order to block reflected radiance as well as to keep the tank completely isolated from the outside (Fig. 1). M-AERI data were taken with a variety of wind speed / wave conditions.

Figure 1.
M-AERI mounted on the ASIST facility at RSMAS. The water in the tank is colored green. The ladder in the foregraound gives scale to the picture.

In September 2001, an infrared imaging camera was installed above the ASIST tank to measure an image of the surface skin temperature. The imager is a FLIR Systems ThermaCAM SC3000 with a 20 degree FOV lens. The camera was mounted directly over a circular opening in the Plexiglas cover of the tank, imaging an area of 30 cm width x 25 cm length. The measurements are in a spectral range of 8-9 μm with an accuracy of ±2° K and a sensitivity of 0.03° K. Images of the water surface temperature were taken at various wind speeds / wave height combinations with concurrent video images of the water surface. Figure 2 depicts an image of skin temperature with a wind speed of approximately 5 m/sec. The bulk temperature of the water in the tank was approximately 310° K.

The in situ sensors involved in this study are taken from the SkinDeEP field instrument and modified for use in the ASIST. High resolution temperature measurements will be made with the Platinum–plated tungsten wire microthermometer (μT), a schematic of which is shown in figure 3. It consists of a 5 μm diameter platinum-plated tungsten wire welded to stainless steel prongs that are tapered to a

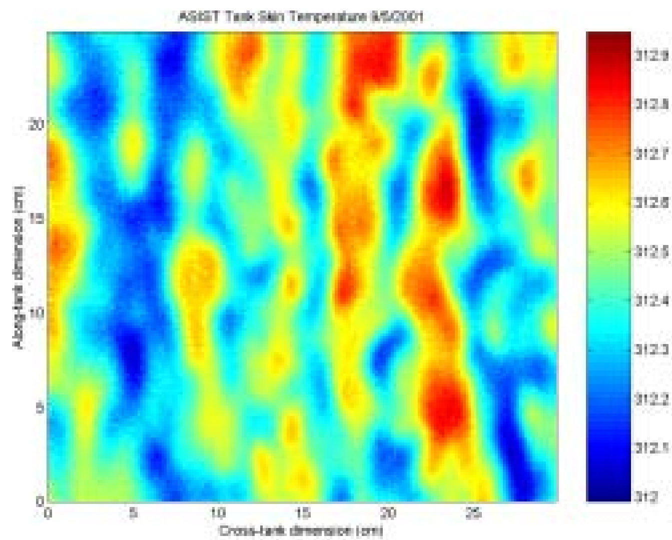

Figure 2.
Eaxmaple of skin temperautre varaitions measured by the infrared imager in the ASIST facility, with a wind speed of ~5ms^{-1}. The area covered is 25x30 cm and the temperature range is 0.95K.

0.1 mm tip. This is mounted onto a ceramic support which in turn is mounted in a stainless steel tube. Due to the inherent drift in the sensor, a thermistor is deployed to provide absolute temperature measurements, also shown in figure 3. The microconductivity sensor in figure 4 provides a way of reliably detecting the water surface in the data record. The sensors are mounted in J-shaped supports and then attached to a linear motor which provides vertical motion through the water column.

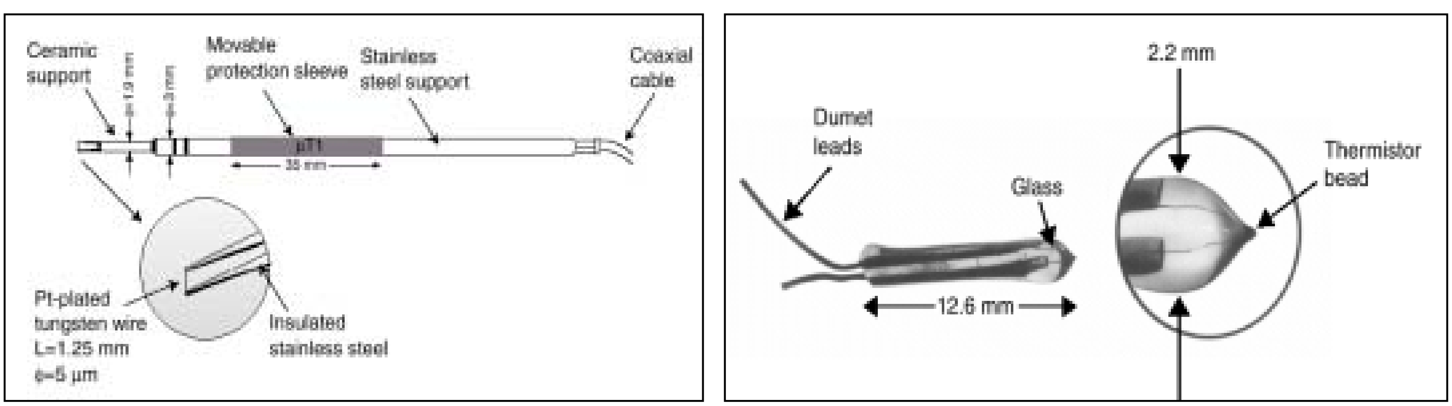

Figure 3.
In situ thermometers for use in the ASIST expriments: Platinum–plated tungsten wire microthermometer (left) and microthermistor (right).

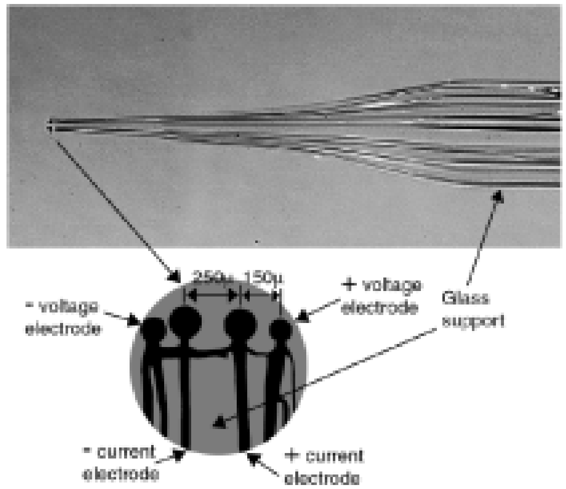

Figure 4.
Microconductivity sensor for use in the ASIST expriments.

An atmospheric correction algorithm for GOES infrared imager data to derive SSTs to support a study of the diurnal signals of SST in near-coastal US waters. The radiative transfer model is based on that of Závody *et al*. (1995). The profiles used to describe the range of variability of the atmospheric state are derived from the output of the ECMWF assimilation model.

RESULTS

The ASIST tests thus far have been to establish that the sensors work and the experimental arrangement is sound. This has been achieved and a second set of measurements is planned for November, 2001. These will include measurements with a variety of wind / wave conditions as well as with varying heat flux conditions between the water surface and the overlying atmosphere.

The GOES SST retrieval algorithm is:

$$SST_{goes} = 1.502 + (0.9508 * T_{11}) + (0.1033 * T_{11-12} * SST_{ref}) + (1.3782 * T_{11-12} *(\sec(\theta)-1)$$

where T_{11} is the GOES brightness temperature at 10.7µm, and T_{11-12} is the difference in brightness temperatures at 12 and 10.7µm; SST_{ref} is a first guess reference temperature and θ is the satellite zenith angle at the surface. The predicted RMS uncertainty in the SST retrievals, based on 4140 simulations is 0.28K. The algorithm is based on that the Miami AVHRR Pathfinder project (Kilpatrick et al, 2001).

IMPACT/APPLICATIONS

The demonstration of the absolute accuracy of the GOES SSTs will open up new research areas related to diurnal signals, and improved understanding of the near surface temperature structure will lead to better determination of air-sea exchanges, as well as the long-term goal of improved techniques of compositing satellite-derived SST fields.

TRANSITIONS

Collaborative work with NAVOCEANO continues with RSMAS providing guidance in algorithm development and improvements that come from the continuing AVHRR Pathfinder studies, and NAVOCEANO providing near-real time *in-situ* data from ocean buoys.

RELATED PROJECTS

This project has benefited from related research being done in the Remote Sensing Group at RSMAS with funding from other federal agencies, specifically instrument development through contracts and grants from NASA and NOAA. The ASIST facility was developed with funding from ONR, DURIP.

REFERENCES

Kilpatrick, K. A., G.P.Podesta and R.H. Evans, 2001. Overview of the NOAA/NASA Pathfinder algorithm for Sea Surface Temperature and associated Matchup Database." *J. Geophys Research* **106,** 9179-9198.

Minnett, P. J., R. O. Knuteson, F.A. Best, B.J. Osborne, J. A. Hanafin and O. B. Brown, 2000. The Marine-Atmosphere Emitted Radiance Interferometer (M-AERI), a high-accuracy, sea-going infrared spectroradiometer. *Journal of Atmospheric and Oceanic Technology*. In review.

Ward, B. and P. J. Minnett, 2001. An autonomous profiler for near surface temperature measurements. *Gas Transfer at Water Surfaces.* edited by M. A. Donelan, W.M. Drennan, E.S. Saltzmann and R. Wanninkhof. *American Geophysical Union Monograph.* In the press.

Ward, B., R. Wanninkhof, P.J. Minnett and M.J. Head., 2002, SkinDeEP: A Profiling Instrument for Upper Decameter Sea Surface Measurements. *Journal of Atmospheric and Oceanic Technology.* In preparation.

Závody, A.M., C.T. Mutlow, D.T. Llewellyn-Jones. 1995. A radiative transfer model for sea-surface temperature retrieval for the Along Track Scanning Radiometer. *J. geophys. Res.,* **100**, 937-952.